Selecting Transformers

As we examined in the labs, transformers are important devices in all power supplies. They allow us to efficiently step up and down AC voltages without any active components. Luckily, their selection process is relatively straight-forward, with only a few key parameters:

1. **Power Output** – Transformers are often rated in VA, or volt-amps. This is a measure of the **combined** RMS output power that the transformer can produce. For example, a transformer with a single secondary winding that produces $V = 18\ V_{AC}\ (RMS)$ at $I = 1\ A$ would be rated at roughly $18\ VA$. Note that transformers may have multiple secondary (output) windings with different voltage and current ratings – the power output is the total of all of these windings.
2. **Primary Voltage** – Power supply transformers should be matched to the input voltage and frequency of the power grid they connect to. For North America, we will usually select 110/115/117/120V transformers – you can consider these all to be the same (slightly different rating standards). Note that some transformers have **multiple** primaries (often rated as 115/230 or similar). These can, through a small wiring change, be connected to any country's electrical grid.
3. **Secondary Voltage** – All transformers are rated in RMS voltage at the secondary. We will need to convert from a peak voltage requirement in most of our design problems.
4. **Secondary Current** – Should meet or exceed the maximum current being drawn through our power supply.
5. **Secondary Type** – The transformer may have a **center tap**; this is a connection to a point half-way along the secondary winding. It divides the total secondary RMS voltage into two equal sources of **half** the original value. We will discuss this issue further during the example.

Once again, there are other subtleties to selection, but the above criteria will be more than enough for this assignment. As before, we will continue an example from the class notes to explain the selection process. Recall again the full-wave example on p. 165 of the notes. The relevant information is copied below:

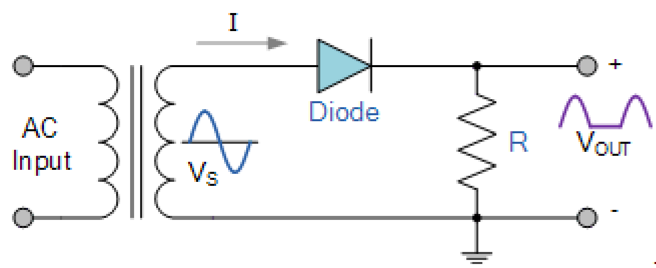
Desired Transformer/Input Specifications
$V_{Transformer_{Peak}} = 13\ V$ $I_{Load} = 1\ A\ (max)$

In the example, we required $V_{IN} > 12\ V$ for the rectifier to operate, with a diode drop of $V_{D_0} = 1\ V$, meaning we need a peak of $13\ V$ or more at the transformer input. Converting to RMS:

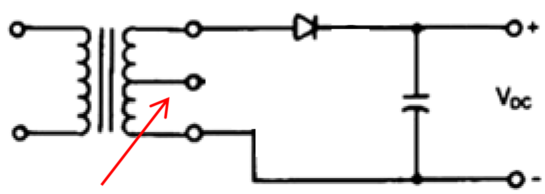
$$V_{transformer_{RMS}} = \frac{13}{\sqrt{2}} = 9.19\ V$$

Transformer Selection Process

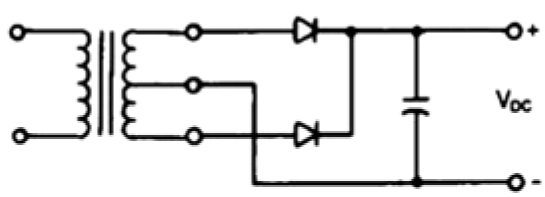
Unlike previous selection examples, we must understand the rectifier type we are using, as it affects the secondary type and voltage we need to search for. Consider the simplest combination of a regular transformer secondary and a half-wave rectifier:



The peak voltage is $V_{S_{Peak}} - V_D$, where $V_{S_{Peak}}$ is the secondary peak voltage and V_D is the diode's forward drop. If our example circuit were of this type, we would pick a **non-center tapped** transformer with a secondary voltage of $V_S \cong 9.2\ V_{RMS}$. Note that a **center-tapped** type **could** be used if the **total** secondary voltage were 9.2 V_{RMS}; we would simply ignore the center tap (red arrow) in this case:



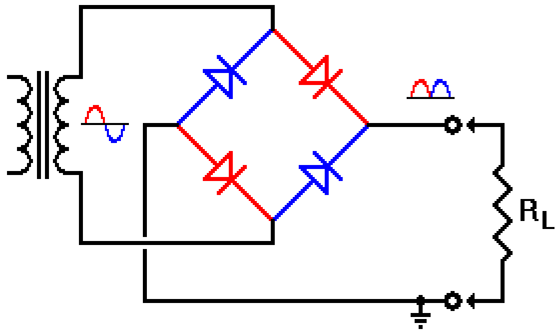
However, this example specified a **full-wave rectifier circuit** using **two diodes**. This particular form of full-wave rectifier **requires** a center-tapped transformer. It must use the following configuration:



In this case, one must note that the total winding voltage of 9.2 V_{RMS} would be divided **in two** by the center tap that we reference as zero volts (negative output). Thus, to maintain the same peak voltage as before, the **total** secondary winding voltage must be doubled:

$$V_{transformer_{RMS}} = 9.2(2) = 18.4\ V$$

So, if you use this transformer type with the two-diode rectifier, you must be cautious of the above. Otherwise, another valid option would be to select our second type of full-wave rectifier, the **bridge rectifier**. The bridge can be used with either a regular **or** center-tapped secondary to provide full-wave rectification (same as the 2-diode circuit above). Note that the center tap is not used in this arrangement.

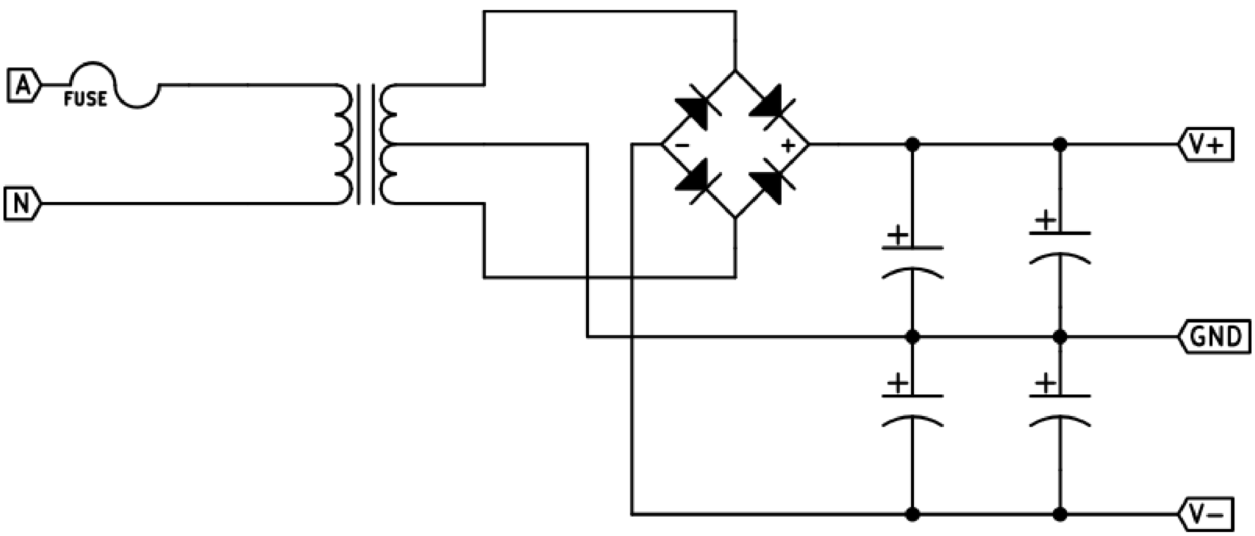


If we choose to use a bridge, one should be careful to note that we always experience **two** diode forward drops rather than one. So, we should increase our required voltage slightly to compensate:

$$V_{transformer_{peak}} = 12 + 2(1.0) = 14\,V$$

$$V_{transformer_{RMS}} = \frac{14}{\sqrt{2}} \cong 10\,V_{RMS}$$

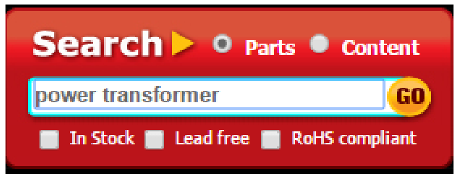
This is everything you need to know for this assignment, as only a single output power supply is required. For your interest, though, there is one additional configuration possible using the bridge and a center-tapped transformer specifically:

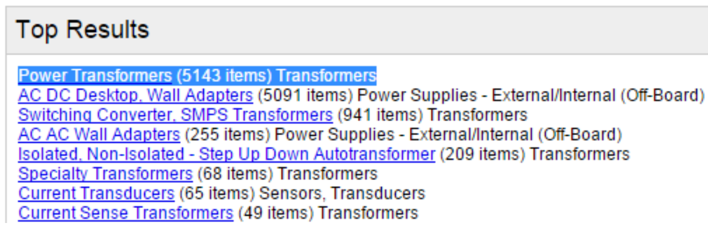


In this arrangement, the bridge produces a positive **and** negative output voltage of **equal** magnitude from a **single** transformer secondary. We will not need this arrangement in this assignment.

Sample Selection

1. As before, go to your preferred parts distributor. I will use Digikey again for this example. Searching for **Power Transformers** yields the correct category:

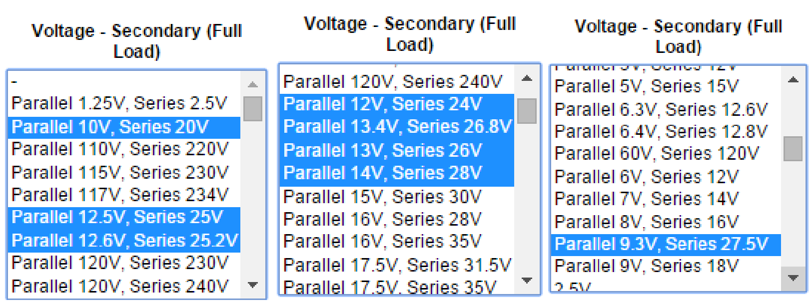




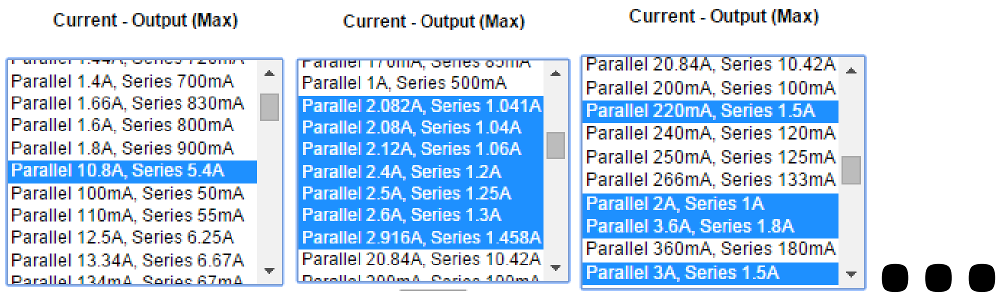
2. We will select secondary voltage first. We require a secondary of $18.4\,V$ center tapped or **slightly higher** (lower will not work – think back to the peak voltage requirement).

When a single number is given under 'Voltage-Secondary', this refers to a non-center tapped transformer. Since this particular circuit used a two-diode full-wave, we **require** a center tap, and can ignore these results. Otherwise, if we used a half-wave or bridge, they can be selected.

Instead, we select only those transformers with the option to have parallel or series secondary (this is another way of referring to a center tapped transformer). We require each winding (parallel voltage) to be around $9.2\ V_{RMS}$, or equivalently around $18.4\ V_{RMS}$ in series. Selecting options close to these values (but not too much higher):



3. Next, we filter by the required current. Note that since we are using the center tap (due to the two-diode full-wave circuit), we **must** use the **series** current rating. Selecting those options greater than $1\ A$ (the given load current), we have the following. Note that I omitted many selections with $I \gg 1A$ due to the large physical size these would have; you can include them if you wish, but they are also likely to be expensive, too.



4. We can now sort the remaining options by our secondary requirements (cost, size, etc.). In this example, I sort by cost and examine a few results:

Compare Parts		Image	Digi-Key Part Number	Manufacturer Part Number	Manufacturer	Description	Quantity Available	Unit Price CAD	Minimum Quantity	Series	Type	Voltage - Primary	Voltage - Secondary (Full Load)	Current - Output (Max)	Primary Winding(s)	Secondary Winding(s)	Center Tap	Power - Max	Mounting Type	Termination Style	Size / Dimension	Height - Seated (Max)
			237-1509-ND	F20-1000-C2-B	Triad Magnetics	XFRMR LAMINATED 20VA THRU HOLE	25 - Immediate	9.33264 @ qty 10,000	1	C2 Split Pack™	Laminated Core	115V	Parallel 10V, Series 20V	Parallel 2A, Series 1A	Single	Dual	No	20 VA	Through Hole	PC Pin	57.15mm L x 47.63mm W	36.50mm
			237-1810-ND	F20-1000	Triad Magnetics	XFRMR LAMINATED THRU HOLE	19 - Immediate	9.66576 @ qty 10,000	1	C2 Split Pack™	Laminated Core	115V	Parallel 10V, Series 20V	Parallel 2A, Series 1A	Single	Dual	No	20 VA	Through Hole	PC Pin	57.15mm L x 47.63mm W	36.50mm
			595-1174-ND	ST-6-20	Signal Transformer	XFRMR LAMINATED 20VA THRU HOLE	1,002 - Immediate	10.31700 @ qty 10,000	1	ST	Laminated Core	115V	Parallel 10V, Series 20V	Parallel 2A, Series 1A	Single	Dual	No	20 VA	Through Hole	PC Pin	57.20mm L x 47.60mm W	36.90mm
			237-1474-ND	FS20-1000-C2-B	Triad Magnetics	XFRMR LAMINATED 20VA THRU HOLE	42 - Immediate	10.86677 @ qty 10,000	1	-	Laminated Core	115V, 230V	Parallel 10V, Series 20V	Parallel 2A, Series 1A	Dual	Dual	No	20 VA	Through Hole	PC Pin	57.15mm L x 47.63mm W	36.50mm
			595-1015-ND	14A-20-20	Signal Transformer	XFRMR LAMINATED 20VA THRU HOLE	363 - Immediate	11.08340 @ qty 10,000	1	One-4-All™	Laminated Core	115V, 230V	Parallel 10V, Series 20V	Parallel 2A, Series 1A	Dual	Dual	No	20 VA	Through Hole	PC Pin	57.20mm L x 47.60mm W	41.30mm
			MT3122-ND	PL20-20-130B	Tamura	XFRMR LAMINATED 20VA THRU HOLE	846 - Immediate	11.31754 @ qty 10,000	1	PL20-xx-130B	Laminated Core	115V, 230V	Parallel 10V, Series 20V	Parallel 2A, Series 1A	Dual	Dual	No	20 VA	Through Hole	PC Pin	57.20mm L x 47.60mm W	41.28mm
			MT3143-ND	PLT20-32-130B	Tamura	XFRMR LAMINATED 20VA THRU HOLE	98 - Immediate	11.31754 @ qty 10,000	1	-	Laminated Core	115V, 230V	Parallel 9.3V, Series 27.5V	Parallel 220mA, Series 1.5A	Dual	Dual	Yes	20 VA	Through Hole	PC Pin	57.20mm L x 47.60mm W	41.38mm
			237-1264-ND	VPS20-1250	Triad Magnetics	XFRMR LAMINATED 25VA CHAS MOUNT	187 - Immediate	11.32336 @ qty 10,000	1	Chassis Mount: World Series™	Laminated Core	115V, 230V	Parallel 10V, Series 20V	Parallel 2.5A, Series 1.25A	Dual	Dual	No	25 VA	Chassis Mount	Solder, Quick Connect	50.80mm L x 49.28mm W	58.67mm

Picking the cheapest result, we **verify** that the primary voltage we need (115V for North America) is supported. If the 'Voltage – Primary' was listed as "115V, 230V" or similar, this indicates it can operate at either voltage, as mentioned earlier. From the above, it appears that the first option is sufficient; if will give a peak output of:

$$V_{transformer} = 10\ V_{RMS} = 14.14\ V_{Peak}$$

$$\therefore V_{rectifier_{output}} = 14.14 - 1 = 13.14\ V_{peak}$$

This exceeds our original requirement slightly (but not too much so that the regulator must waste significant power). The current capability is also exactly what we need (1A series), so this transformer is suitable.